



**US Army Corps
of Engineers®**
Walla Walla District



**United States
Environmental Protection Agency
Region 10**

DREDGED MATERIAL MANAGEMENT PLAN AND ENVIRONMENTAL IMPACT STATEMENT

McNary Reservoir and Lower Snake River Reservoirs

APPENDIX K Aquatic Resources

**DRAFT
October 2001**

**FINAL
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**FINAL DREDGED MATERIAL MANAGEMENT PLAN AND
ENVIRONMENTAL IMPACT STATEMENT
McNary Reservoir and Lower Snake River Reservoirs**

JULY 2002

**ERRATA SHEET
FOR
APPENDIX K - AQUATIC RESOURCES**

This appendix has not been substantially changed from the draft and will not be reprinted. Please make the following changes to the draft appendix and consider the draft appendix with corrections as the final appendix.

Front cover:

Apply the attached label (FINAL, July 2002) on the front cover to the right of the draft date.

Footnotes throughout the appendix:

Change all footnote references from "Draft DMMP/EIS, October 2001" to "Final DMMP/EIS, July 2002."

Section 1.1 Background

Page K-1, 2nd paragraph

Last sentence should read:

The DMMP/EIS will direct a course of action for managing the removal and disposal of sediment over the next 20 years in a means focused toward providing beneficial uses [e.g., increased habitat quantity and/or quality for species listed under the Endangered Species Act (ESA)].

Section 5.0 Critical Habitat Considerations

Page K-25, 1st full paragraph

5th sentence:

Change 70 °F to 73 °F.

Section 7.3 Dredging Areas and Quantities

Page K-30

Insert after 3rd paragraph:

In 2001, the Woody Riparian Development Program was established under the authority of the Lower Snake River Fish and Wildlife Compensation Plan. As an alternative to the RM 116 disposal site, the Corps may use in-water disposal to build up shoreline for woody riparian habitat development at RM 132 adjacent to the Chief Timothy Habitat Management Unit in Lower Granite Reservoir. The portion of the site that could be used for the 2002-2003 disposal consists of a shallow sloping bench (about 10 feet deep at maximum operating pool) extending along about 4,000 feet of shoreline. This site has a capacity of approximately 550,000 cubic yards and it is anticipated that this site would be filled to about 60 percent capacity with the

material dredged during the 2002 –2003 dredging activity. Dredged material disposal at RM 132 is designed to accomplish three goals: (1) create planting zones for woody riparian habitat, (2) increase suitability and acreage of shallow water rearing habitat for Snake River fall chinook juveniles, and (3) dispose of dredged material in a beneficial manner.

Dredged material placement in 2002-2003 could occur in a manner that extends the shore riverward along the proposed reach in an effort to create an approximately 18 lineal acre planting bench for riparian species that would be submerged within the water surface elevation range between 736 and 738 feet m.s.l. The Lower Granite reservoir maximum operating pool is elevation 738 feet m.s.l. and minimum operating pool is elevation 733 feet m.s.l. The overall plan is to place sand in the below-water portion of the area, extending riverward of the riparian embankment, to enhance fall chinook rearing suitability of 16 acres of mid-depth habitat bench by decreasing the depth. Silt would be used to cap the riparian bench and dredged cobbles would be placed around the perimeter of the bench in a one-foot thick band to provide armoring to protect the bench from wave action. The riparian bench surface area would vary from about 150 feet to 400 feet wide by 4,000 feet long.

*** * * END OF CHANGES * * ***

**DREDGED MATERIAL MANAGEMENT PLAN
AND ENVIRONMENTAL IMPACT STATEMENT**

McNARY RESERVOIR AND LOWER SNAKE RIVER RESERVOIRS

**APPENDIX K
AQUATIC RESOURCES**

prepared for:

**U.S. Army Corps of Engineers
Walla Walla District
201 North 3rd Avenue
Walla Walla, WA 99362**

prepared by:

**U.S. Army Corps of Engineers
Walla Walla District
Walla Walla, WA 99362**

with the assistance of:

**David H. Bennett, Ph.D.
Moscow, ID 83844-1136**

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EXECUTIVE SUMMARY

Construction of the Snake River and Columbia River federal dams altered the character of the natural river from running to impounded water and created over 124 miles [200 kilometers (km)] of reservoirs on the lower Snake River and 62 miles (100 km) of reservoir behind McNary Lock and Dam (McNary) on the Columbia River. A continuing effect of dam construction is the deposition of sedimentary material in the lower velocity areas within the system, creating problems with aquatic habitat and system management, including changes in aquatic biota and interference with navigation and flood control. The Walla Walla District Corps of Engineers (Corps) is proposing to conduct navigation and maintenance dredging on the lower Snake River, mid-Columbia River (specifically McNary reservoir in Washington and Oregon), and at the mouth of the Clearwater River in Idaho and Washington.

The Dredged Material Management Plan and Environmental Impact Statement (DMMP/EIS) for the lower Snake River and McNary reservoirs is being developed to restore the authorized depth of the navigation channel, remove sediment from port areas, provide for recreational use, and provide for irrigation of wildlife habitat and recreation sites. The DMMP/EIS will direct a course of action for managing the removal and disposal of sediment over the next 20 years in a means focused toward providing beneficial uses (e.g., increased habitat quantity and quality for species listed under the Endangered Species Act).

The purpose of this report is to provide an ecological analysis of management alternatives proposed to address the sedimentation problems. A ranking matrix was developed for the 12 initially proposed sediment management alternatives. Criteria used to evaluate the proposed alternatives included aspects of the life cycle of migrating salmonids and resident fishes, their food production, and maintaining the biological integrity of the five reservoir ecosystems. Effects of implementation of each of these alternatives on each criterion were evaluated relative to a possible beneficial, deleterious, or neutral effect. Scores were obtained for each of the alternatives and those with the highest scores (i.e., positives exceeded negatives) were considered to be biologically acceptable alternatives.

Six land disposal alternatives were examined in the selection process for the preferred alternative. Some alternatives provided for direct land disposal whereas others provided for construction of a temporary in-water storage area (Alpowa Creek site) followed by later removal and land disposal. All alternatives that remove large volumes of dredged material requiring temporary in-water storage, however, were deemed deleterious to the aquatic habitat based on factors including the potential blockage to Alpowa Creek to upstream migrating steelhead (*Oncorhynchus mykiss*) and elimination of potential rearing habitat for subyearling chinook salmon (*O. tshawytscha*) in the reservoir.

Six in-water alternatives were identified, ranging in volume of disposal from less than 300,000 cubic yards (CY) [229,367 cubic meters (m³)] per year to approximately 2,000,000 CY (1,529,110 m³) per year. Selectively placed in-water disposal is considered beneficial and could ultimately enhance habitat conditions in the reservoir ecosystem. The degree of benefit to the Lower Granite ecosystem is based upon the type of in-water disposal used. Maximum benefit to all aquatic fauna would accrue from shallow water disposal, such as shallow shoreline

construction, whereas the least benefit would accrue from deep-water disposal. This conclusion was based on results from studies of experimental in-water disposal of dredged material in Lower Granite reservoir where subyearling chinook salmon used shallow water habitat surrounding Centennial Island and several introduced fishes, considered game fishes, benefited from the increase in shallow water habitat. Experimental deep-water disposal was considered neither deleterious nor beneficial to the Lower Granite ecosystem.

Based on a thorough analysis of potential benefits, the Corps selected a preferred alternative from the screened alternative list and formulated a Recommended Plan for long-term management of dredging. Alternative 4 - Maintenance Dredging with Beneficial Use of Dredged Material and a 3-Foot (0.9-Meter) Levee Raise, would best meet environmental criteria based upon restoration of valuable shallow water sand bar habitat used by endangered juvenile salmonids in the Lower Snake River.

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1.0 INTRODUCTION

1.1 Background

Construction of the Snake River and Columbia River federal dams altered the character of the natural river from running to impounded water and created over 124 miles [200 kilometers (km)] of reservoirs on the lower Snake River and 62 miles (100 km) of reservoir behind McNary Lock and Dam (McNary) on the Columbia River. A continuing effect of dam construction is the deposition of sedimentary material in the lower velocity areas within the system, creating problems with aquatic habitat and system management, including changes in aquatic biota and interference with navigation and flood control. For example, in Lower Granite Lock and Dam (Lower Granite) reservoir, sediment deposition has occurred around the confluence of the Snake and Clearwater Rivers and downstream to Silcott Island. The Walla Walla District Corps of Engineers (Corps) is proposing to conduct navigation and maintenance dredging on the lower Snake River, mid-Columbia River (specifically McNary reservoir in Washington and Oregon), and at the mouth of the Clearwater River in Idaho and Washington.

The Dredged Material Management Plan and Environmental Impact Statement (DMMP/EIS) for the lower Snake River and McNary reservoirs is being developed to restore the authorized depth of the navigation channel, remove sediment from port areas, provide for recreational use at boat launches, and provide for irrigation of wildlife habitat and recreation sites. The DMMP/EIS will direct a course of action for managing the removal and disposal of sediment over the next 20 years in a means focused toward providing beneficial uses [e.g., increased habitat quantity and quality for species listed under the Endangered Species Act (ESA)].

The purpose of this report is to provide an analysis of the initial 12 alternatives proposed by Corps personnel to alleviate the sedimentation problem in the lower Snake River reservoirs. A number of management alternatives have been examined in the past (Meyer and Sather-Blair, 1988). Most have involved removal of sediment through dredging and either in-water or land disposal, both of which alter the physical habitat in the reservoir. Dredging and disposal of material can afford a substantial opportunity for habitat changes. Changes in the physical habitat can alter the habitat suitability for various species and can be either beneficial and increase the suitability and availability of habitat or can be detrimental and result in less suitable habitat (Bennett et al., 1998). Improved suitability can result in increased abundance and overall increased biological production; conversely, decreased suitability can result in decreased abundance or even extirpation of a species from a given area. Although dredging activities are expected to occur at specific sites throughout the lower Snake River and McNary reservoirs, the confluence of the Snake and Clearwater Rivers is considered to be the most ecologically sensitive and, therefore, was used as the baseline for assessing the dredging alternatives.

In the late 1980's, the Corps organized a regional Interagency Working Group for technical review of dredge management proposals for the Snake and Clearwater Rivers confluence area and a proposal to use in-water disposal of dredged material for beneficial use within the Lower Granite reservoir. The Interagency Working Group determined that not enough technical information was available to accept the assumptions generated for estimating benefits of creating aquatic habitat with in-water disposal of dredged material, or which design of habitat

components would be most suitable for salmonid and resident species. The Group directed that an experimental pair-wise comparison study be conducted where long-term monitoring for species composition, utilization, and habitat parameter quality would be compared between established reference sites and created habitat sites composed of shallow water versus mid-depth versus deep water. The study would prioritize beneficial use based upon suitability for salmonid species first, then unsuitability for fish species that prey on juvenile salmonids.

Experimental in-water disposal of dredged material was initiated in 1988. A total of over 20 reference sites representing existing shallow water, mid-depth benches, and deep-water habitat were established for comparison to two in-water disposal sites. Approximately 900,000 cubic yards (CY) [688,099 cubic meters (m³)] of sediment was used in 1988 to raise a mid-depth bench [originally 20 to 40 feet (6 to 12 meters (m)) deep] to a depth of 6 to 12 feet (2 to 4 m), thereby creating a shallow water underwater plateau. In 1989, a linear island referred to as Centennial Island was created immediately atop the downriver segment of the underwater plateau. A mid-channel site at River Mile (RM) 120, offshore and slightly downriver of Centennial Island, was used as the comparable deep-water disposal experimental site. Monitoring of the fish and benthic macroinvertebrate communities began in 1988 and continued through 1994, with ancillary studies conducted through 1997 to supplement components and variables in the database.

An adaptive management framework guided annual study objectives, which evolved as the study years progressed. The primary objectives included:

- Assess age-0 chinook salmon (*Oncorhynchus tshawytscha*) abundance in Lower Granite reservoir, identify critical habitat components and function, then assess the potential suitability of the experimental disposal sites for rearing of age-0 chinook salmon.
- Compare benthic community structure and abundance at experimental disposal sites and reference sites.
- At experimental in-water disposal sites and reference sites, monitor and compare abundance of larval, juvenile, and adult resident fish species that are predators upon juvenile salmonids [with emphasis on the northern pike minnow (*Ptychocheilus oregonensis*) and smallmouth bass (*Micropterus dolomieu*)].
- Estimate juvenile salmonid consumption by predators in Lower Granite reservoir.
- Assess white sturgeon (*Acipenser transmontanus*) abundance and habitat components associated with their abundance in Lower Granite reservoir.

1.2 General Description of Alternatives

Twelve dredging alternatives were developed to deal with the sedimentation problems in Lower Granite reservoir (table K-1). Dredging-related actions within the alternatives for the DMMP/EIS consider the volume of sediment to be removed on a yearly basis [up to

2,000,000 CY (1,529,110 m³) and from where it is to be removed from the river channel using established templates. Additional actions include the location for disposal of material (either in-water or at an upland site) and to what extent the levee system near the confluence of the Snake and Clearwater Rivers would be modified to provide adequate flood protection.

Table K-1 - Alternatives and General Descriptions of Dredging-Related Actions.

Alternative	General Description
1a	Navigational Maintenance - In-Water Disposal
1b	Navigational Maintenance - Upland Disposal
2a	12-foot Levee Raise - Navigational Maintenance - In-Water Disposal
2b	12-foot Levee Raise - Navigational Maintenance - Upland Disposal
3a	8-foot Levee Raise - Dredge 300,000 CY - In-Water Disposal
3b	8-foot Levee Raise - Dredge 300,000 CY - Upland Disposal
4a	4-foot Levee Raise - Dredge 1,000,000 CY - In-Water Disposal
4b	4-foot Levee Raise - Dredge 1,000,000 CY - Upland Disposal
5a	3-foot Levee Raise - Dredge 1,000,000 CY - In-Water Disposal
5b	3-foot Levee Raise - Dredge 1,000,000 CY - Upland Disposal
6a	No Levee Raise - Dredge 2,000,000 CY - In-Water Disposal
6b	No Levee Raise - Dredge 2,000,000 CY - Upland Disposal

2.0 ECOLOGICAL ANALYSIS

2.1 Dredging-Related Actions and Ecological Issues

Most of the dredging actions will have impacts on aquatic species, and specific biological criteria were chosen for assessing the various alternatives. The primary criteria used to evaluate the proposed alternatives include aspects of the life cycle of salmonids and resident fishes, their food production, and the biological integrity of the five reservoir ecosystems. Although other species of concern, including threatened or endangered species, are known to seasonally exist in the area [e.g., Snake River sockeye salmon (*Oncorhynchus nerka*) and bull trout (*Salvelinus confluentus*)], of specific interest was the juvenile life stage of fall chinook salmon (*O. tshawytscha*) and the rearing stages of white sturgeon (*Acipenser transmontanus*), both of which exist for extended periods near the confluence of the Snake and Clearwater Rivers. Effects of implementation of each of these alternatives using these criteria were evaluated relative to possible beneficial, deleterious, or neutral impacts.

2.2 Fall Chinook Salmon

2.2.1 Background

Subyearling fall chinook salmon (subyearlings) found along the shorelines of the lower Snake River reservoirs are believed to be progeny of adult fall chinook salmon that spawned either in the free flowing portion of the Snake and Clearwater Rivers or possibly in tailwaters of impoundments on the lower Snake River. Little is known about timing of emergence from the

gravel for Snake River fall chinook salmon (Howell et al., 1985); however, Bennett and Shrier (1986) and Bennett et al. (1988, 1990, 1991, 1993a, 1993b) captured subyearlings in Lower Granite reservoir in April, suggesting emergence can occur in March to early April. Most juvenile fall chinook salmon from the Snake River migrate to the ocean as subyearlings (Bjornn, 1960). The wild juvenile fall chinook typically pass mid-June through September, with double peaks in mid-July, and some lingering proportion of the annual migration population lasting until December. Passive Integrated Transponder (PIT)-tag detections of 1993-1995 brood year juvenile fall chinook salmon from the Clearwater River were recorded in the spring of 1994-1996 at some lower Snake River dams (Arnsberg, 1996). It is apparent from these detections that some fall chinook salmon migrate to the ocean as yearlings, rather than as subyearlings.

After 2 to 3 years in the ocean, adult wild Snake River Fall Chinook Salmon return to the Snake River between late summer and early winter with spawning activity beginning around mid-October (Connor et al., 1994). The majority of redds annually appear clustered in specific areas, such as RM 162 in 1991 (Connor, 1997). Spawning of fall chinook salmon has also been known to occur in Little Goose Lock and Dam (Little Goose), Lower Monumental Lock and Dam (Lower Monumental), and Ice Harbor Lock and Dam (Ice Harbor) reservoirs, but only in tailwater areas directly downstream of the dams' bypass outfalls, where water velocity is high and substrate is relatively large (Dauble et al., 1995 and 1996).

2.2.2 Habitat Preference

After emergence and initial dispersal, subyearlings in both Lower Granite and Little Goose reservoirs are consistently collected over sand substrate and in areas of reduced velocity (Curet, 1993). Beach seine haul sampling by Curet (1993) suggests that subyearlings were concentrated over suitable micro-habitats where conditions such as temperature and dissolved oxygen levels remain at levels conducive for rearing. Bennett and Shrier (1986) and Bennett et al. (1988, 1990, 1991, 1993a, 1993b) captured subyearlings over low gradient, low velocity, sandy substrates in Lower Granite reservoir. In addition, subyearlings rearing along the shoreline of Lower Granite reservoir during the spring exhibit a strong selection for substrata consisting of primarily sand and a moderate avoidance of cobble/sand and talus/sand (Curet, 1993). Curet (1993) also found a strong avoidance of riprap habitat consistent for all years analyzed (years 1990-1992).

In the unimpounded mid-Columbia River, Becker (1970) showed that subyearlings use relatively slow moving waters near the shorelines or immediately downriver of islands for resting and feeding. These findings are consistent with subyearling collections in the Hanford Reach of the Columbia River where subyearlings use shoreline areas of reduced current velocity for resting and feeding (Dauble et al., 1989). The reason for the higher abundance of subyearlings over sand substrate is not clear; however, it is likely an anti-predation strategy at locations that produce suitable macroinvertebrate prey abundance. Conversely, another study has indicated that low velocities may be more important in influencing rearing potential than the prevailing substrate (Bennett et al., 1992b). Habitat selection studies, conducted for many salmonid species, generally suggest that larger fish inhabit deeper and faster water (Dauble et al., 1989).

2.2.3 Seasonal Habitat Use

Bennett et al. (1987-1998) and Curet (1993) sampled subyearlings primarily by beach seining and open water trawling. The estimated population size of subyearlings along the shoreline of Lower Granite reservoir peaked between mid-May and the first week of June; however, the duration of subyearlings rearing along the shoreline of the reservoir differed between years. In 1987 and 1992, subyearlings disappeared from the shoreline by late May; whereas, in 1990 and 1991, subyearlings remained along the shoreline until late June. In Little Goose reservoir, the estimated peak population of subyearlings was found along the shoreline in mid-May to early June but no subyearlings were typically collected there after mid-July. Population estimates by river reach indicated that the highest numbers of subyearlings reared mid-reservoir between RM's 83.4-103.4 followed by the areas between RM's 70.2-83.4 and RM's 103.5-106.9.

Curet (1993) found that the overall rearing period for subyearlings in Lower Granite reservoir was 75 days in 1992 and 112 days in 1991, in both cases less than in John Day reservoir on the Columbia River (greater than 160 days) (Sims and Miller, 1981). The open water rearing period was most similar between the two years at 27 and 28 days, for 1992 and 1991, respectively. Mid-water and bottom trawl collections in Lower Granite reservoir during June 1992 indicated that after the subyearlings migrate from the shoreline of the reservoir in late spring, the fish appeared to be pelagically oriented in mid-depth to deep water areas before beginning their downriver migration. The 27- to 28-day open-water rearing period observed for subyearlings in Lower Granite closely coincided with results from subyearling collections in the unimpounded lower Snake River between Lower Granite reservoir and Hells Canyon Dam. Connor et al. (1992) noted an approximate 30-day difference between peak shoreline abundance and peak arrivals of subyearlings at Lower Granite. Duration of open water rearing appeared to be related to temperature and was similar for both 1991 and 1992.

2.2.4 Temperature and Habitat Use

Temperature appears to regulate the duration of shoreline residence and downriver movement of the fish. Subyearlings appeared to be distributed primarily along the shoreline of the reservoir during their early rearing period in the reservoirs and pelagically oriented once shoreline temperatures exceed 64 to 68 °F (18 to 20 °C). Based on results from 1987, 1990, 1991, and 1992, duration of littoral rearing was longer in the cooler years [i.e., producing higher runoff flows (Curet, 1993)]. Littoral rearing differed from 48 days in 1992 to 84 days in 1991. In 1990 and 1991, when shoreline temperatures remained below 64 °F (18 °C) until mid to late June, subyearlings remained along the shoreline until late June. Peak abundance along the shoreline of the reservoir occurred in late May to early June, 2 weeks later than in 1987 and 1992, which were lower flow years of more rapidly warming shoreline temperatures. As increasing water temperatures result in water too warm for shoreline rearing, subyearlings may move offshore into deeper, faster areas where they rear until commencing their downriver migration.

In addition, since they are not afforded the additional year of rearing and overwintering in the subbasins as exhibited by yearling chinook salmon, subyearlings migrate through reservoirs more slowly than yearling chinook salmon and spend more time in reservoir habitats for rearing

(Rondorf et al., 1990; Curet, 1993). Subyearling migration rates through the reservoir also depend on growth and subsequent degree of smoltification.

2.2.5 Predator Relationships

The most likely beneficial effect of shallow water habitat creation identified through 10 years of monitoring data was the effect of creating more refuge habitat suitable to juvenile fall chinook for rearing during their subyearling migratory life stage. However, the fidelity exhibited by subyearlings for shoreline rearing in the reservoir and the unimpounded lower Snake River above Lower Granite reservoir may compromise survival since these areas are shared with a number of predators (Curet, 1993; Connor et al., 1992; Bennett et al., 1988).

Smallmouth bass and northern pike minnow are both predators of subyearlings. Smallmouth bass appear to be the most serious predator along the shorelines of Lower Granite reservoir, consuming up to 6 percent of the wild subyearling population rearing and migrating through Lower Granite reservoir (Curet, 1993). Curet (1993) estimated mean daily consumption rates of subyearlings for three length groups of smallmouth bass [less than 10 inches (250 millimeters (mm)), 10 to 15 inches (250 to 389 mm), and greater than 15 inches (389 mm)] collected in May 1992 and two length groups of northern pike minnow [10 to 14 inches (250-349 mm) and greater than 14 inches (349 mm)] collected during the smolt out-migration period (April through June) in 1987-1991. Daily consumption rates of subyearlings by smallmouth bass were similar between the less-than-10-inch (250-mm) and 10- to 15-inch (250- to 389-mm) length groups at 0.06 and 0.09 prey/predator/day, respectively. No consumption was noted by the greater-than-15-inch (389-mm) length group although low numbers of smallmouth bass at this size were sampled. Daily consumption rates of subyearlings by northern pike minnow ranged from 0.01 to 0.06 prey/ predator/ day for the 10- to 14-inch (250- to 349-mm) and greater-than-14-inch (349-mm) length groups, respectively.

In earlier discussions of the results collected from the first few years of Bennett's studies in Lower Granite reservoir, a much wider range of fish-to-habitat linkages were considered likely. It readily appeared that some of these more complex linkages were unlikely in importance as critical indicators and not worth concentrating on due to their decreased priority in ecological significance. The focus readily highlighted the need to pay greater attention to larval fish and associated macroinvertebrate and limnologic surveys in very shallow water around the created island as compared to the reference sites. It appeared less important to carefully examine for complex habitat distribution throughout the reservoir.

The primary difference between suitable juvenile fall chinook salmon rearing habitat and juvenile predator species (northern pike minnow and smallmouth bass) is the preference for some cover structure by pike minnow and bass. Thus, open sand substrate without cover provides refuge for juvenile fall chinook since juvenile predator species tend to avoid areas without cover, although they prefer shallow water sand or cobble substrate for feeding during the warming periods of the reservoirs [similar to warming periods in the unimpounded lower Snake River (Petersen et al., 1999) and reaches of the Columbia River]. During the active monitoring phase of the Lower Granite reservoir habitat utilization studies, the discussions of predator population dynamics, predation on juvenile salmonids, and the links relating fish to habitat

focused much more closely on the critical importance of the shallow water habitat overlapping utilization by juvenile fall chinook and those juvenile northern pike minnow and smallmouth bass typically too young or small to directly consume the juvenile salmon.

2.2.6 Prey Relationships

Food habits and the caloric importance of prey were assessed for four length groups [1.5 to 2 inches (40 to 50 mm), 2 to 3 inches (56 to 70 mm), 3 to 3.5 inches (71 to 85 mm), and greater than 3.5 inches (86 mm)] of subyearlings collected in Lower Granite and Little Goose reservoirs, Washington, during 1991-1992 (Curet, 1993). Ephemeropterans and cladocerans were the most important prey item for the 1.5- to 2-inch (40- to 50-mm) size class, ephemeropterans and dipterans were the most important prey items for the 2- to 3-inch (56- to 70-mm) and 3- to 3.5-inch (71- to 85-mm) size classes, and larval fish were the most important prey item (72 percent) in the diet of fish greater than 3.5 inches (86 mm). Application of a bioenergetics model estimated that subyearlings were feeding at 27 percent of their maximum ration during the time interval modeled (April-July). The observed proportion of maximum ration was only 7 percent greater than the estimated maintenance ration (zero growth) modeled for the same time interval suggesting either forage limitations, competition, or other abiotic and biotic factors may be influencing subyearling growth in the reservoir (Curet, 1993).

The application of a bioenergetics model, used in analysis of stomach contents of subyearlings (Curet, 1993), suggests temperatures may dictate shoreline distribution and timing of downriver migration. Both specific growth rates (calories/gram predator/day) and daily weight increments for subyearlings declined once water temperatures exceeded 55 °F (13 °C). At temperatures exceeding the preferred range of 54 to 57 °F (12 to 14 °C) (Brett, 1952), the metabolic demands of subyearling chinook begin to exceed the fish's ability to consume adequate forage to maintain optimal growth, a phenomena considered a trigger for out-migration. Migration from the shoreline of Lower Granite reservoir occurred once water temperature exceeded 64 °F (18 °C), coinciding with the model predicted cessation and reduction of weight gain and growth rates (Curet, 1993). Curet's (1993) results suggest reservoir and shoreline temperature greatly influence the duration of shoreline and open water rearing period of subyearlings and, hence, their fitness to survive downriver migration. Based on data from John Day Lock and Dam (John Day) reservoir (Sims and Miller, 1981), neither rate of downriver movement nor residence time of subyearlings is influenced by river velocities.

2.3 White Sturgeon

2.3.1 Background

Historically, diadromus white sturgeon in the Columbia and Snake Rivers system ranged freely and made extensive seasonal migrations to optimize changing habitats (Bajkov, 1951). Development and operation of the Columbia and Snake Rivers hydrosystem has altered the natural riverine habitat suitable for white sturgeon by modifying historic flow regimes and sedimentation, temperature, dissolved oxygen, and accessibility and diversity of food supplies (Coon et al., 1977; Haynes and Gray, 1981; Lukens, 1981; Ebel et al., 1989; Parsley and Beckman, 1992). In addition, dams and resulting impoundments have served to isolate white

sturgeon populations (North et al., 1992). The watershed has further been impacted by logging, agriculture, mining, stream channelization, water pollution, and harvest allowing some species of fish to flourish while others decline. Populations of fish species adapted to riverine conditions typically decline at the highest rate (Parsley et al., 1992). Landlocked populations of white sturgeon in the Snake River in Idaho are classified as a species of special concern (Mosley and Groves, 1990 and 1992) for the states of Washington and Idaho.

2.3.2 Abundance and Habitat Use

White sturgeon are generally considered less abundant in each upriver impoundment in the Columbia and Snake river system. Comparison of fish density in Lower Granite reservoir with Columbia River impoundments concluded density of white sturgeon in Lower Granite reservoir [0.94 fish/acre (0.38 fish/hectare)] was lower than reported in Bonneville Lock and Dam (Bonneville) reservoir [15.12 fish/acre (6.12 fish/hectare)] and The Dalles Lock and Dam (The Dalles) reservoir [6.20 fish/acre (2.51 fish/hectare)] but slightly higher than John Day reservoir [0.74 fish/acre (0.30 fish/hectare)] (Beamesderfer and Rien, 1992). The lower Columbia River below Bonneville Dam supported the highest density [36.08 fish/acre (14.6 fish/hectare)] of white sturgeon in the Pacific Northwest, with this attributed to abundant food resources available due to fish having access to the ocean (Devore et al., 1992).

White sturgeon remain relatively abundant in the Snake River between Lower Granite (RM 107.5) and Hells Canyon Dam (RM 247.2) (Lepla, 1994, Cochnauer, 1983; Cochnauer et al., 1985; Lukens, 1985). White sturgeon studies conducted prior to Lepla (1994) in this area mainly described the population status above Lower Granite reservoir with little data on fish residing in the reservoir environment proper. Coon et al. (1977) estimated 8,000 to 12,000 white sturgeon [greater than 18 inches (46 centimeters (cm)) total length (TL)] in the Snake River between Hells Canyon Dam and Lower Granite during 1972-1975. Lukens (1984) reported an estimate of 4,000 white sturgeon between the confluence of the Snake and Clearwater Rivers and Hells Canyon Dam but failed at efforts in collecting white sturgeon in Lower Granite reservoir.

Presence of young of year (YOY) and high abundance of juvenile white sturgeon in Lower Granite reservoir indicated recruitment occurring in the Lower Granite-Hells Canyon population. The high abundance of juvenile and YOY fish near the upper end of Lower Granite reservoir also suggests that the reservoir primarily serves as rearing habitat. McCabe and Tracy (1992) suggested wide dispersal of white sturgeon larvae allowed more use of feeding and rearing habitats while minimizing competition. Lepla (1994) assumed no spawning occurred in Lower Granite reservoir since velocities measured in the reservoir [0 to 2 feet per second (0.0 to 0.60 m/sec)] are below threshold levels perceived to elicit spawning [3 feet per second (1.0 m/sec)] (Anders and Beckman, 1992).

Monitoring of fish stocks in 1992 and 1993 by Bennett et al. (1994) sampled 320 white sturgeon yielding an estimate of 1,804 [95 percent Confidence Interval (CI) of 816 to 7,219]. This estimate (1,804) is similar to Lepla's (1994) estimate of 1,372, indicating abundance of white sturgeon in Lower Granite reservoir remained similar and was assumed to be relatively stable following Lepla's (1994) surveys during 1991 and 1992. Density of white sturgeon in Lower Granite reservoir is also similar to densities reported above Lower Granite reservoir from past

surveys. Although direct comparisons were not possible, density of white sturgeon in Lower Granite reservoir of 45 fish/RM was similar to 38 fish/RM reported above Lower Granite reservoir by Lukens (1985) but lower than estimates by Coon et al. (1977). Coon et al. (1977) estimated white sturgeon densities ranging from 56 to 85 fish/RM between Lower Granite and Hells Canyon dams while Lepla's (1994) estimate for Lower Granite reservoir alone was 19 to 72 fish/RM (average of 45 fish/RM).

2.3.3 Population Structure

Gillnet and setline sampling was used by Lepla (1994) to estimate population structure in Lower Granite reservoir. White sturgeon collected with gill nets ranged in length from 4 to 80 inches (10.3 to 203 cm) tail fork length (FL) with a mean of 24.5 inches (62.3 cm) FL. White sturgeon collected with setlines ranged from 27 to 93 inches (69 to 236 cm) FL with a mean of 50 inches (127.3 cm) FL. The corrected length frequency distribution indicated juvenile white sturgeon measuring less than 44 inches (112 cm) FL [49 inches (125 cm) TL] comprised 94 percent of the length distribution indicating juvenile and young-of-the-year (YOY) fish. Mature adult white sturgeon [greater than 49 inches (125 cm) TL] were not using Lower Granite reservoir with the same frequency as juveniles. A sample of 504 white sturgeon were determined to be from 0 to 29 years of age. Juvenile white sturgeon from ages 0 to 8 comprised 84 percent of the entire sample with the 1986-87 year-classes indicated as being weak. A plot of length at age data indicated growth was relatively consistent up to age greater than 8.

Comparison of mean lengths of juvenile white sturgeon from Lower Granite reservoir and Columbia River impoundments (Miller and Beckman, 1992) indicated mean lengths were longer in Lower Granite reservoir. Higher growth rates for Snake River white sturgeon relative to Columbia River populations may result from warmer water, lower densities, and less competition for food resources. Similar studies comparing Columbia River impoundments and the lower Columbia River determined juvenile white sturgeon from Columbia River impoundments had greater length-at-age and condition than fish from the lower Columbia River citing increased food availability and lower densities (Miller and Beckman, 1992). An additional factor of less turbidity in the reservoir environment than in the riverine environment may enhance search and capture efficiency on the two to three abundant species left in the overall lower diversity of prey species.

Mean length at age has increased significantly for white sturgeon compared to previous surveys in the Lower Granite to Hells Canyon dam reach. Mean lengths of white sturgeon for ages 5 to 18 years in Lower Granite reservoir were longer than lengths of similarly aged fish during 1972-1975 (Coon et al., 1977) and 1982-1983 (Lukens, 1984). This increase in growth over past surveys in the Lower Granite to Hells Canyon Dam reach may, in part, be related to sampling a juvenile population from an impoundment. White sturgeon from 1972-1975 and 1982-1983 surveys were primarily sampled in riverine sections above Lower Granite reservoir that may have accounted for slower growth rates. Miller and Beckman (1992) reported that faster growth of juvenile white sturgeon in the Columbia River occurred in impoundments rather than in the lower Columbia River, suggesting faster growth was related to increased food availability. The general principle of reservoir aging suggests a possible factor of less prey diversity with increased aging of the reservoir where only two to three species remain, but each of these species

was in significantly higher abundance, equaling a net increase in availability of a suitable (although not particularly the most preferred) food base.

Comparison of length at age data with white sturgeon in the C. J. Strike Dam to Bliss Dam reach (RM 494.0 to 560.3) of the middle Snake River indicated growth was similar for ages 4 to 14 years. Growth rates in that reach appeared higher than in Lower Granite reservoir for ages less than 3 and greater than 14 years. Cochnauer (1983) reported white sturgeon in the middle Snake River exhibited higher growth rates due to warmer water. The more recent operations, where cold Dworshak Dam (Dworshak) reservoir water and cool Hells Canyon water is used to augment lower Snake River flows for endangered salmon, could result in a lower number of adequately warm degree days for white sturgeon growth compared to historical conditions.

Low frequency of white sturgeon from the 1986-1987 year classes suggested potential low recruitment to the population during those years. Year class failures have been observed in white sturgeon populations (Miller and Beckman, 1992) with implications that the environment affects white sturgeon reproduction more than stock-recruitment relations during some years and in some areas (Parsley et al., 1992). Numerous environmental conditions can potentially impact white sturgeon recruitment over several years and life stages with water flow receiving recent attention. Spring flows in the Hells Canyon reach associated with 1986-1987 year classes were relatively high compared to the following lower water years associated with the onset of the drought in the middle Snake River Basin. In addition, hydraulic dredging conducted near the Port of Wilma during 1987 may have contributed to mortality of YOY and juvenile white sturgeon rearing in this area. Buell (1992) reported that hydraulic dredging in the Columbia River seriously injured and killed juvenile white sturgeon and speculated that dredging operations may have attracted feeding sturgeon.

2.3.4 Prey Relationships

Cochner (1981) reported crayfish and chironomid species were dominant food items identified from white sturgeon stomachs in the middle Snake River. Highest densities of crayfish in Lower Granite reservoir, a prey item of white sturgeon greater than 18 inches (45 cm) long (Scott and Crossman, 1973), occurred near the upper end of the reservoir, which coincided with the highest densities of juvenile white sturgeon. Lepla's (1994) sampling in 1990-1991 showed that the upriver portion of Lower Granite reservoir is the most critical portion of the reservoir for juvenile white sturgeon rearing. In addition, Bennett et al. (1990) reported high abundance of larval fishes above RM 127.2, which also may contribute to food resources available to white sturgeon.

2.4 Invertebrate Species

2.4.1 General Information

As reservoirs age, the invertebrate species composition and abundance convert from lotic flowing riverine macroinvertebrate species to lentic or pelagic reservoir micro-invertebrate species found drifting in the photic zone of the reservoir. In the early 1980's, shoreline distributed littoral areas [less than 15.5 feet (5 m) deep] generally had the highest invertebrate

abundance, species diversity, and species evenness. Sites of similar depth within the reservoir appeared different based upon location in the reservoir (as defined by river mile) with regard to benthic invertebrate numbers within and across species (Bennett and Shrier, 1986; Bennett et al., 1988). Bennett et al. (1988) showed a statistically weak pattern of biomass and abundance when measured by season and depth. The shallow water biomass peaks in summer at about 7.5 ounces per square foot (oz/ft²) [20 grams per square meters (g/m²)], and drops off to around 1.9 oz/ft² (5 g/m²) in the winter. Measured by depth, the biomass appears to be constant from 5 to 20 feet (1.5 to 6 m) deep, but begins to decrease as depth increases below 20 feet (6 m). Dorband (1980) found a shift in dominant benthic taxa within a few years after reservoir filling at RM 83.9, approximately four-fifths the distance up-reservoir from Lower Granite near the Port of Wilma. The Port of Wilma is approximately where the hydraulic influence of the unimpounded flow input becomes dominated by the backwater effect of the reservoir volume and lower water velocities.

By the early-to-mid 1980's, the dominant benthic invertebrate taxa in Lower Granite reservoir had converted to dipteran chironomid midges and annelid oligochaete blood worms (Bennett and Shrier, 1986; Bennett et al., 1988). Upriver of RM 83.9, there were more lotic species (larvae of tricopteran caddisflies, ephemeropteran mayflies, and plecopteran black flies) while, below RM 83.9, lentic taxa were common (dipteran chironomid midges and annelid oligochaete blood worms). Based upon the relatively young age of the reservoir, zooplankton densities in Lower Granite reservoir were low [2 to 177 organisms/gallon (1 to 46 organisms/liter)] in the late 1970's (Funk et al., 1985) and the highest abundances were in protected or quiescent areas. Annual and seasonal population abundance variations occurred, with increased variation evident for species exhibiting seasonal emergence (e.g., chironomids as they pupated into adults) than species that are aquatic through all life stages (e.g., oligochaetes).

Species abundance and composition for benthic macroinvertebrates sampled in the early 1980's (5 to 7 years following refill) were related to habitat differences including substrate type and size, depth, flow, and season of year (Bennett and Shrier, 1986; Dorband, 1980). Species diversity of macroinvertebrate communities at shallow sites increases with downstream movement or colonization of drifting organisms scoured from upriver habitats, provided that like substrate and associated habitat components are available and suitable. The transition zone between the lentic and lotic habitats had the lowest density of benthic macroinvertebrates possibly attributable to deposition from sediment input where the average water velocity across the channel slows. Benthic macroinvertebrates that are commonly consumed by salmonids in Lower Granite reservoir also seem to be largely taxa that are commonly associated with hard substrates. Nightingale (1999) reported differences in the macroinvertebrate fauna of hard versus soft substrates in the lower Snake River reservoirs.

2.4.2 Crayfish

One species of crayfish, the signal crayfish (*Pacifastacus leniusculus*) has been found in Lower Granite reservoir (Lepla, 1994, and Anglea, 1997). Its habitat seems to be linked with substrate, as it is a hiding form and not burrowing. This species of crayfish is aggressive, mobile, and grows and reproduces rapidly (Lowery and Holdich, 1988). Anglea (1997) and Naughton (1998) have both demonstrated that crayfish constitute a significant dietary item for smallmouth bass

(*Micropterus dolomieu*), and others (Bennett and Shrier, 1987; Bennett et al., 1988; Chandler, 1993) have reported on their significance as food for northern pike minnow (*Ptychocheilus oregonensis*) and channel catfish (*Ictalurus punctatus*). Numbers of signal crayfish collected from upstream areas, having more riverine habitat type, were considerably higher than in downstream areas (Lepla, 1994, and Anglea, 1997).

Crayfish have been found at all depths in the Oxbow reservoir above Hells Canyon (Bennett, 1995), in Lower Granite reservoir during the physical drawdown test in 1992 (Bennett et al., 1995a; Curet, 1994), and in the unimpounded Snake River between Lower Granite reservoir and Hells Canyon Dam (Nelle, 1999). Number of crayfish ranged from 0 to 1 animal collected at lower reservoir (RM 108.0) transects to 267 animals collected at RM 133.5. The majority (81 percent) of crayfish were sampled at upper reservoir transects. Crayfish predominantly inhabit shallow water riprap areas from which they forage riverward for oligochaetes and other soft substrate inhabitants.

The role of crayfish in resident and predatory fish diets is extensively reported for every year of sampling in both Lower Granite reservoir (Bennett, 1988) and in the unimpounded Snake River upriver of Lower Granite reservoir (Nelle, 1999; Petersen et al., 1999), especially for sustaining northern pike minnow and smallmouth bass. A Spearman's rank correlation indicated high correlation between crayfish and white sturgeon distribution ($r_s = 0.81$). Also demonstrating the importance of crayfish in sustaining predator productivity between Lower Granite and Hells Canyon Dam, Bennett et al. (1995a) observed a vertical migration of smallmouth bass with the 2 feet (0.6 m) per day receding water during the physical drawdown test of Lower Granite reservoir in March 1992. Crayfish were left desiccated as they searched for wetted shelter in the sediment cracks of the 30-foot- (9-m-) deep zone that was dewatered for several weeks. When the reservoir refilled in late March and early April and spring chinook smolts began migrating, smallmouth bass (the majority of which survived) vertically migrated back up to the shallow water zones that had cover via riprap. Smallmouth bass consumption rates on juvenile salmonids increased in 1992 compared to previous smolt migration years as a consequence of interception by predators that were occupying a littoral zone that was temporarily devoid of crayfish. Crayfish recruited back to the littoral zone with the year, and smallmouth bass consumption rates on juvenile salmonids decreased in 1993 to similar rates estimated for previous and post years of sampling (Bennett et al., 1995a; Bennett et al., 1997).

2.4.3 Oligochaetes

Oligochaetes (blood worms) are found throughout the lower Snake River reservoir sediments and prefer fine sediments with a high percent of organic content. Their biomass does not appear to vary with depth of water. While the numerical densities can fluctuate widely with a pattern similar to chironomids, the average biomass density appears to remain relatively constant around 1.9 oz/ft² (5 g/m²). Because oligochaetes are an important food item for crayfish, impacts to their populations may indirectly affect populations of anadromous and resident fish species.

2.4.4 Chironomids

Chironomid populations within the lower Snake River reservoirs are composed of several different species and can make up a substantial portion of the diets of certain fishes. Chironomids are most likely located in sand-silt sediments and decrease in both finer and coarser sediment type environments. This results in chironomids being readily susceptible to predation by rearing salmonid smolts across the smolt migration seasons, during each of the overlapping pupation and emergence episodes of the various chironomid species. If food is a limiting resource to fall chinook salmon rearing and migrating through Lower Granite reservoir, then it is necessary to estimate chironomid densities as a function of depth and substrate type.

2.4.5 Corophium

Although more studies are needed, studies on the Columbia River have shown the importance of benthic invertebrates, particularly *Corophium salmonis*, in diets of juvenile white sturgeon (McCabe et al., 1992a; McCabe et al., 1992b). Corophium species abundance in Lower Granite reservoir appeared to be low (Bennett et al., 1991); however, Sprague et al. (1992) indicated that white sturgeon might be feeding on organisms in the water column rather than exclusively on organisms associated with the substrate. Corophium species (river drift organisms) were the predominant prey item eaten by YOY and juvenile white sturgeon in two Columbia River impoundments and the lower Columbia River (Sprague et al., 1992; McCabe et al., 1992a; Muir et al., 1988).

3.0 ANALYSIS OF DREDGING-RELATED ACTIONS AND ALTERNATIVES

3.1 Dredged Material Removal

Dredging in Lower Granite reservoir has the potential to make substantial changes in the physical habitat, especially by altering the substrate, velocity, and depth characteristics. In general, the two major sediment removal templates for the confluence area include dredging down to the original river channel bed only in areas required for navigation, or establishing a larger footprint of the river bottom with greater volumes removed [up to 2,000,000 CY (1,529,110 m³) annually].

3.1.1 Positive Impacts

Ecologically, a number of benefits would accrue from dredging to the original river channel including maintenance of "original" riverine like habitat for white sturgeon (*Acipenser transmontanus*) and production of riverine-like benthic macroinvertebrates. Lepla (1994) convincingly demonstrated the importance of the habitat in upstream areas of Lower Granite reservoir for white sturgeon. Approximately 56 percent of Lepla's total white sturgeon captures were made in the original river channel of Lower Granite reservoir from Highway 28 (Red Wolf) Bridge to the confluence of the Snake and Clearwater Rivers. Lepla's distribution of spatial abundance of white sturgeon was also nearly identical to that for crayfish, an important food item for white sturgeon in Lower Granite reservoir. The two main habitat factors likely to change with dredging are higher velocities and larger substrate. Therefore, dredging to the depth of the

natural channel would be beneficial for maintenance of suitable habitat for white sturgeon and crayfish. The most biologically appealing aspect of the expanded footprint is that the dredging activity would be localized into one area as proposed by the U.S. Fish and Wildlife Service (Meyer and Sather-Blair, 1988).

Several taxa of aquatic organisms commonly found in the stomachs of juvenile anadromous salmonids in Lower Granite reservoir were from organisms produced on firm substrates (Karchesky, 1996). Hard substrata in Lower Granite reservoir occur along riprap (Nightingale, 1999) and the original river channel. Some of these organisms “drift” in the upstream portion of Lower Granite reservoir primarily in the seasons of higher flow that increases their availability to rearing and downstream migrating juvenile salmonids and resident fishes. Therefore, dredging that could improve the “natural” integrity of the bottom of the river channel in the upstream portion of Lower Granite reservoir and would be beneficial to the production and potential availability of macroinvertebrates to fishes.

3.1.2 Negative Impacts

Ecologically, the upstream end of the reservoir is probably the most important habitat area of Lower Granite reservoir for both resident fishes and food items for juvenile anadromous salmonids (Curet, 1993; Lepla, 1994). Dredging alternatives that expand the current footprint have the potential to substantially alter this important aquatic habitat. Under various alternatives that include use of the expanded dredging footprint, the natural river bottom would be removed to create a large, localized “sump” for sediment collection. From a biological perspective, repeated large volume dredging in the area identified for the expanded footprint would deleteriously affect the ecosystem. In some areas, dredging up to 20 feet (6 m) below the current river bottom would shift the river bottom to below the photic zone, thereby reducing primary productivity. Effects could include loss of benthic macroinvertebrate production and, in turn, loss of fish rearing habitat.

3.1.3 Determination

The existing river channel in the upstream area of Lower Granite reservoir is ecologically important habitat for fall chinook salmon and white sturgeon. Dredging the larger volumes of material would effectively lower some areas in the confluence area below the photic zone, resulting in lower overall productivity. In addition, any substantial loss of aquatic habitat may compromise the integrity of the Lower Granite reservoir ecosystem. Dredging volumes of 1 to 2 million CY (764,555 to 1,529,110 m³) annually would eliminate much of the important existing habitat in the confluence area and reduce the productivity of the area following dredging. Alternatives that would increase impacts to this area, including dredging amounts from 1 to 2 million CY (764,555 to 1,529,110 m³) annually, are considered ecologically unacceptable. Although a sediment removal volume of 300,000 CY (229,367 m³) per year follows the same template as the 1,000,000 CY (764,555 m³) plan, the volume of material to be removed over the course of the dredging plan is substantially less and, therefore, less detrimental over time. This volume is less preferred than the navigation channel maintenance dredging, however, which would remove less of the existing shallow water habitat.

3.1.4 Analysis of Alternatives

The two options of larger amounts of dredging, encompassing alternatives 4a, 4b, 5a, 5b, 6a, and 6b were determined to be biologically unacceptable. Dredging up to 300,000 CY (229,367 m³) per year (3a and 3b) was acceptable but less preferred than navigation channel maintenance.

3.2 Upland Disposal Activities

3.2.1 Positive Impacts

Positive effects of upland disposal have been identified in the DMMP/EIS. Beneficial uses may include capping of disposal sites at the Hanford Nuclear Reservation or use as fill material at other local upland areas. Other uses of some of the material may include building of roadbeds, riparian habitat restoration, or even using the silt material in potting soil mixtures. Habitat restoration efforts may be conducted at some of the Corps-owned habitat management unit (HMU) sites or topsoil capping of dredged material islands in the Columbia or Snake River for habitat improvement. In addition, contaminated sediments removed from the aquatic environment may be taken to a disposal area where they will pose fewer environmental hazards.

3.2.2 Negative Impacts

Some of the upland disposal alternatives include dike construction and filling of aquatic habitats in the Alpowa Creek area south of Silcott Island. In contrast, others provide for direct land disposal with no in-water storage. Presently, little information exists on the ecological importance of the aquatic habitat south of Silcott Island. Fall chinook salmon rear along shorelines of Lower Granite reservoir in surrounding areas to Silcott Island (Bennett et al., 1999) but too little sampling has been conducted in this specific area to assess its rearing habitat potential for fall chinook salmon. Also, backwaters in the lower Snake River reservoirs provide important and often limited habitat for rearing of larval, juvenile, and adult fishes (Bennett et al., 1983). These backwaters often warm faster, contain temperatures that are often higher and closer to optimum temperatures for rearing resident fishes, and provide low velocity habitat alternatives to the main channel reservoir habitat. Bratovich (1985) demonstrated that backwaters in Little Goose reservoir were the habitats most commonly used for rearing by larval resident fishes and Bennett et al. (1988) reported the importance of low velocity areas in Lower Granite reservoir for larval fish rearing habitat. Lower Granite reservoir currently has very limited backwater habitat and further loss is considered detrimental to the system. In addition, work in the area of the mouth of Alpowa Creek may block upstream migrating adult steelhead (*Oncorhynchus mykiss*) that may spawn in Alpowa Creek (Mendel, 1997).

3.2.3 Determination

All of the alternatives that included temporary in-water storage of material or dike construction at Alpowa Creek were considered unacceptable. Several factors contribute to the undesirable aspects of these alternatives, including potential blockage to Alpowa Creek to upstream migrating steelhead, loss of wetlands and aquatic habitat, and elimination of potential rearing habitat for subyearling chinook salmon. Although upland disposal would have few negative

impacts if temporary in-water storage were not used, there would also be no additional benefits to the aquatic habitat. Effects of alternatives that employ temporary storage are deemed deleterious to the aquatic habitat.

3.2.4 Analysis of Alternatives

Six upland disposal options were examined in the selection process for the preferred alternative. Alternatives 1b, 2b, and 3b provide for direct land disposal whereas alternatives 4b, 5b, and 6b provide for construction of a temporary storage area (Alpowa Creek site) followed by later removal and land disposal. All alternatives that remove larger volumes of dredged material and require temporary in-water storage are deemed unacceptable. Alternatives 4b, 5b, and 6b are three alternatives that are considered unacceptable for these reasons.

3.3 In-Water Disposal

3.3.1 Positive Impacts

Chipps et al. (1997) showed that construction of shallow water habitat with dredged material has increased habitat complexity in Lower Granite reservoir and proper placement has potential as an enhancement technique. Six fishes were sampled in an area prior to shallow in-water disposal in Lower Granite reservoir compared to 11 species of fish at the same area following in-water disposal. Chipps et al. (1997) concluded that islands constructed from dredged material altered the “natural” reservoir habitat by decreasing depth and, therefore, improved rearing habitat for several resident fishes.

Differences in habitat suitability also exist for habitat created by dredged material depending upon substrate size. For example, at the island site in Lower Granite reservoir, the shoreward station with sandy substrate often supported a different fish community structure (station 1) than the channel side (station 2), which was armored with cobbles/boulders to secure the shoreline. Species that prefer larger substrate, such as smallmouth bass, were consistently collected in higher abundance along the larger substrate than in the area with finer substrate, without armoring of larger substrate. Therefore, data suggest that fish community structure can also be “fine tuned” with manipulation of the size of substrate as well as changes in depth.

Bennett et al. (1998) showed that fall chinook salmon used the shallow waters surrounding Centennial Island in Lower Granite reservoir. In some years, as many as 10 percent of the total sample of subyearling chinook salmon from Lower Granite reservoir originated from the habitat created by in-water disposal. Bennett et al. (1998) reported that fall chinook salmon were most commonly collected over lower gradient shorelines having low velocities and sandy substrate. Habitat having these physical characteristics can be effectively constructed in any of the lower Snake River reservoirs with appropriate placement of dredged material.

The third potential benefit of in-water disposal in the lower Snake River reservoirs could be in increasing the availability and possible abundance of benthic macroinvertebrates. Bennett et al. (1988, 1990, 1991, 1993) consistently reported no differences in benthic macroinvertebrate abundance between shallow and deep-water habitats in Lower Granite reservoir. However, prey

items for fall chinook composed the higher percentage of the total biomass in shallow water versus deep and mid-depth water. In addition, other investigators have reported that abundance of macroinvertebrates can be higher in shallow water than in deep waters. Therefore, because more than 90 percent of the lower Snake River reservoirs are typically considered mid-depth or deep water [greater than 20 feet (6 m) in depth], converting existing mid-depth benches to shallow water habitat could increase prey abundance for juvenile fall chinook salmon. Bennett and Shrier (1987), Bennett et al. (1988), and Karchesky (1996) clearly demonstrated the importance of benthic macroinvertebrates in Lower Granite reservoir to downstream migrating salmonids. Dipterans and ephemeropterans were highly abundant in the stomachs of juvenile anadromous steelhead and spring/summer chinook salmon in Lower Granite reservoir. However, the abundance and availability of benthic macroinvertebrates to downstream migrating salmonids seems to differ throughout the reservoir. Muir and Coley (1996) showed that stomachs from a large proportion of juvenile salmonids collected at Lower Granite were empty, suggesting either low food abundance near the dam or the lack of feeding. Since others have demonstrated food in the stomachs of juvenile salmonids throughout their downstream migration, the data indicate that low food availability may be a factor in the feeding of salmonids near Lower Granite and possibly other lower Snake River dams. The morphometry of the area surrounding the forebay may be one reason for the low presence of food in stomachs of juvenile salmonids collected at Lower Granite. The shoreline in the forebay is steep and water depth is great [greater than 100 feet (30 m)] and food abundance seems to be limited to pupating and terrestrial insects (Muir and Coley, 1996). Although not known, downstream migrating juvenile salmonids probably do not forage at those extreme depths. Therefore, dredged material might be effectively deposited to enhance the abundance and availability of benthic macroinvertebrates for food to juvenile salmonids in the forebay of Lower Granite and possibly other lower Snake River dams.

Several water quality attributes could be changed by in-water disposal of dredged material. Creating more shallow water habitat could increase the availability of warmer near-shore waters in all of the lower Snake River reservoirs. Currently, water temperatures are below optimum throughout the growing season for all resident game fish. Higher water temperatures could enhance annual growth increments and possibly result in higher survival and higher standing crops. Effects of higher water temperatures in shallow waters on anadromous salmonids are unknown. Curet (1994) reported that subyearling chinook salmon migrate from shallow shoreline areas to deeper waters in the spring/summer when shoreline temperatures attain 64 °F (18 °C). These data indicate that if water temperatures warmed earlier in the spring up to 64 °F (18 °C), growth rates of subyearling chinook salmon and possibly their survival might be enhanced.

Experimental deep-water disposal was not considered deleterious to the Lower Granite ecosystem (Bennett et al., 1997) but not beneficial either for fishes. The principal benefit of deep-water disposal appears to be associated with the potential to increase the availability of benthic macroinvertebrates to downstream migrating salmonids in downstream areas near Lower Granite and possibly other lower Snake River dams. Although theoretically valid, deep-water disposal would unlikely significantly increase water velocities and, therefore, decrease travel time of downstream migrating salmonids through Lower Granite and other lower Snake River reservoirs.

Also, in-water disposal could theoretically decrease reservoir depth; decreased depth may enhance the water velocity through the reservoirs. Higher water velocities might decrease the migration period of juvenile salmonids through Lower Granite and possibly other lower Snake River reservoirs. However, although this may be an important fish management goal, very large quantities of dredged material would be required to significantly alter the migration rates of juvenile salmonids through the reservoir.

3.3.2 Negative Effects

Few negative effects are anticipated from shallow in-water disposal. Potentially, contaminated material could remain undetected and be re-deposited at an in-water site; however, this scenario is not anticipated. Short-term loss of productivity at disposal sites may occur due to covering the existing riverbed; however, invertebrates would rapidly repopulate the new habitat. Disposal of material in deep water was shown to have little ecological benefit and because long-term benefits were not identified, the deep-water disposal action was discarded.

3.3.3 Determination

The degree of benefit to the Lower Granite system is based on the type of in-water disposal used. Maximum benefit would accrue from shallow water disposal, such as island construction and shallow shoreline construction, whereas the least benefit would accrue from deep-water disposal. As indicated earlier, subyearling chinook salmon use shallow water habitat surrounding Centennial Island, the number of fishes has been about doubled, and several introduced fishes, considered game fishes, benefit from the increase in shallow water habitat. Carefully planned and executed shallow in-water disposal will increase shallow water habitat and, in turn, increase productivity of the reservoir system, benefiting various resident and anadromous fish species. Alternatives using primarily in-water disposal are preferred to those using primarily upland disposal.

3.3.4 Analysis of Alternatives

Six in-water alternatives have been identified, ranging in volume of disposal from less than 300,000 CY (229,367 m³) per year to approximately 2,000,000 CY (1,529,110 m³) per year. In-water disposal actions that incorporate beneficial use, primarily habitat enhancement, would be the preferred option from a biological perspective. Although no alternatives were eliminated based on this action, alternatives using primarily in-water disposal are more preferred than those using primarily upland disposal. Therefore, alternatives 1a, 2a, 3a, 4a, 5a, and 6a are more preferable to 1b, 2b, 3b, 4b, 5b, and 6b.

3.4 Levee Modifications and Construction

3.4.1 Positive Impacts

Few positive ecological impacts in Lower Granite reservoir are anticipated with any of the proposed levee raise options. One long-term benefit, however, may include limiting the potential of excess pollutants from entering the river during extreme flood events or chemical spills. For

example during high flood events, preventing structures, sewage treatment ponds and possibly petroleum products from being washed into the river can be considered an ecological benefit. Also, additional levees may aid in preventing potential disasters, such as oil or chemical spills, from directly entering the river in areas where levees do not presently exist, allowing for clean-up activities to occur with reduced intrusion into the river system.

3.4.2 Negative Impacts

Most anticipated negative ecological impacts to the levee raise options are considered short term. Construction and raising of levees would take place outside the present normal wetted perimeter of the river. Impacts to some riparian zones may occur with new levee construction. Also, levee raises of 8 to 12 feet (2.5 to 4 m) would require expansion of the levee footprint; however, that would occur landward rather than riverward. The impacts of most concern are those associated with construction activities. As the height of the proposed levee system increases, more construction activity would be required, thus increasing the potential of environmental problems (including hazardous chemical spills, etc.).

3.4.3 Determination

Because levee construction and raises have few positive or negative aquatic ecological impacts, no alternatives were discarded based on these activities. However, because raising levees in excess of 4 feet (1.2 m) would require a great deal of construction work to shoreline areas, including creating new levees, raising bridges, and relocating buildings, railroad tracks, and roads, more construction activities in the floodplain would be required. Alternatives with no to lower levee raises [0 to 4 feet (0 to 1.2 m)] are preferred to the higher raises [8 to 12 feet (2.5 to 4 m)].

3.4.4 Analysis of Alternatives

Because the higher the levee system is raised, the more construction activities would occur, the potential for short-term negative impacts is increased with higher raises. Although this activity was not used to eliminate any of the alternatives from a biological standpoint, raises from 0 to 12 feet (0 to 4 m) were ranked as most preferred to least preferred according to increasing height. In addition, raises of less than 4 feet (1.2 m) in elevation were much more preferred than those exceeding 4 feet (1.2 m). Alternatives 1a, 1b, 4a, 4b, 5a, 5b, 6a, and 6b were, therefore, more preferred than 2a, 2b, 3a, and 3b.

4.0 OVERVIEW OF ALTERNATIVES

Results of the biological analysis for the 12 alternatives proposed are summarized in table K-2.

Table K-2. Summary of Dredging Alternatives Analyzed Using Biological Criteria.

Alternative	Description	Disposal	Levee	Dredging	Result
1a	Navigational Maintenance - In-Water Disposal	P		A	Acceptable - Preferred
1b	Navigational Maintenance - Upland Disposal	L		A	Satisfactory - Less Preferred
2a	12-foot Levee Raise - Navigational Maintenance - In-Water Disposal	P	L	A	Acceptable - Less Preferred
2b	12-foot Levee Raise - Navigational Maintenance - Upland Disposal	L	L	A	Satisfactory - Less Preferred
3a	8-foot Levee Raise - Dredge 300,000 CY - In-Water Disposal	P	L	A	Acceptable - Less Preferred
3b	8-foot Levee Raise - Dredge 300,000 CY - Upland Disposal	L	L	A	Satisfactory - Less Preferred
4a	4-foot Levee Raise - Dredge 1,000,000 CY - In-Water Disposal	P	L	U	Unacceptable
4b	4-foot Levee Raise - Dredge 1,000,000 CY - Upland Disposal	L	L	U	Unacceptable
5a	3-foot Levee Raise - Dredge 1,000,000 CY - In-Water Disposal	P	L	U	Unacceptable
5b	3-foot Levee Raise - Dredge 1,000,000 CY - Upland Disposal	L	L	U	Unacceptable
6a	No Levee Raise - Dredge 2,000,000 CY - In-Water Disposal	P	P	U	Unacceptable
6b	No Levee Raise - Dredge 2,000,000 CY - Upland Disposal	L	P	U	Unacceptable
U = Unacceptable A= Acceptable P=Preferred L=Less Preferred					

4.1 Alternative 1a. Navigational Maintenance - In-Water Disposal

This alternative provides one of the highest potential benefits to the lower Snake River reservoirs (see Section 2.0, ECOLOGICAL ANALYSIS). Dredging would be similar to that done experimentally from 1986-1992 and its effects along with shallow water disposal were considered positive on the lower Snake River reservoirs. Both anadromous and resident fishes could benefit from this alternative, if in-water disposal were conducted to enhance shallow water habitat. Based on these reasons, this alternative should be considered one of the **Acceptable** alternatives.

4.2 Alternative 1b. Navigational Maintenance - Upland Disposal

This alternative provides for one potential benefit to the lower Snake River reservoirs: dredging would be of similar magnitude to that done experimentally since 1986. Based on the various criteria, dredging could have a positive effect although no aquatic ecological benefits would accrue from upland disposal. Negative impacts were associated with anadromous fishes and food abundance. However, total ecosystem impact of this alternative would be minor and this alternative could be considered **Satisfactory**. Alternative 1b should be considered as a **Satisfactory** alternative as long as upland disposal does not require temporary in-water disposal.

4.3 Alternative 2a. 12-foot Levee Raise - Navigational Maintenance - In-Water Disposal

Alternative 2a, from an aquatic ecological standpoint, would have overall similar effects to alternative 1a. Based on the criteria, this alternative provides for one of the highest potential benefits to anadromous fishes in the lower Snake River reservoirs. Dredging would be similar to that done experimentally since 1986 and was, therefore, considered positive to the lower Snake River ecosystem. If in-water disposal were conducted to enhance shallow water habitat, this alternative could also have positive effects to both anadromous and resident fishes and should be considered as one of the **Acceptable** alternatives.

4.4 Alternative 2b. 12-foot Levee Raise - Navigational Maintenance - Upland Disposal

Alternative 2b, from an aquatic ecological standpoint, would have similar overall effects as alternative 1b since the summary scores were similar. Dredging would be similar to that conducted experimentally since 1986 and that aspect of this alternative was considered positive. Because the benefits of shallow in-water disposal did not occur, the upland disposal did not score positively to the lower Snake River ecosystem. As with alternative 1b, anadromous fishes and food abundance were negatively affected. However, alternative 2b should be considered as a **Satisfactory** alternative as long as upland disposal does not require temporary in-water disposal.

4.5 Alternative 3a. 8-foot Levee Raise - Dredge 300,000 CY - In-Water Disposal

Alternative 3a was evaluated as having an effect on both anadromous and resident fishes similar to alternatives 1a and 2a. Dredging was evaluated to have benefits similar to other alternatives that provided for dredging to the original channel depth and the benefits of shallow in-water disposal have been indicated. For these reasons, alternative 3a was considered as an **Acceptable** alternative.

4.6 Alternative 3b. 8-foot Levee Raise - Dredge 300,000 CY - Upland Disposal

Alternative 3b was another alternative that rated in the ranking similarly to the previous alternatives. Effects of the limited dredging were considered beneficial although with upland disposal, no in-water benefits to either resident or anadromous fishes were seen. As with alternatives 1b and 2b, the most negative effects were associated with anadromous fishes and food abundance. Alternative 3b should be considered a **Satisfactory** alternative as long as upland disposal does not require temporary in-water disposal.

4.7 Alternative 4a. 4-foot Levee Raise - Dredge 1,000,000 CY - In-Water Disposal

Alternative 4a, from an aquatic ecological standpoint, was found to potentially have more deleterious effects than beneficial effects. Effects of dredging were highly negative because the large quantity was considered to require an expanded dredging footprint beyond that of dredging to the original channel depth. This alternative should be considered as **Unacceptable**. However, if dredging were to be completed without the expanded footprint and with shallow water disposal, this alternative could be considered **Satisfactory**.

4.8 Alternative 4b. 4-foot Levee Raise - Dredge 1,000,000 CY - Upland Disposal

Alternative 4b, from an aquatic ecological standpoint, would have similar deleterious effects as other proposed alternatives that require an expanded footprint and because of the large volume of material that would require temporary in-water disposal. Upland disposal would not provide any in-water disposal benefits, and the temporary in-water storage would result in a permanent habitat loss. This alternative scored negative for dredging and, with loss of associated habitat, should be considered **Unacceptable**.

4.9 Alternative 5a. 3-foot Levee Raise - Dredge 1,000,000 CY - In-Water Disposal

From an aquatic ecological standpoint, alternative 5a, similar to alternative 4a, was found to potentially have more deleterious effects than beneficial effects. Effects of dredging were highly negative because the large quantity of dredged material was considered to require an expanded dredging footprint beyond that of dredging to the original channel depth. With the expanded footprint, this alternative should be considered **Unacceptable**. However, if dredging were to be completed without the expanded footprint and with shallow water disposal, this alternative could be considered **Satisfactory**. This alternative provides for some potential benefits to the lower Snake River reservoirs with shallow in-water disposal and, thus, scored positive for the in-water disposal but the positive scores were offset by the large-scale dredging effort.

4.10 Alternative 5b. 3-foot Levee Raise - Dredge 1,000,000 CY - Upland Disposal

This alternative provides nearly total negative scores to the lower Snake River reservoirs. The proposed large-scale dredging footprint, along with the required temporary in-water disposal, scored negative. As a result, this alternative should be considered **Unacceptable**.

4.11 Alternative 6a. No Levee Raise - Dredge 2,000,000 CY - In-Water Disposal

From an aquatic ecological standpoint, alternative 6a, similar to alternatives 4a and 5a, would have more potentially deleterious effects than beneficial effects. Effects of dredging were considered highly negative because the large quantity of dredged material would require an expanded dredging footprint beyond that of dredging to the original channel depth and even beyond the template for 1,000,000-CY alternatives. With the expanded footprint, this alternative should be considered **Unacceptable**. This alternative provides for some potential benefits to the lower Snake River reservoirs with shallow in-water disposal and, thus, scored positive for the in-water disposal but the positive scores were offset by the large-scale dredging effort.

4.12 Alternative 6b. No Levee Raise - Dredge 2,000,000 CY - Upland Disposal

Alternative 6b, from an aquatic ecological standpoint, would have overall deleterious effects from the expanded dredging footprint and required temporary in-water storage and habitat loss. The large volume of dredging, combined with the temporary in-water disposal, makes this alternative **Unacceptable**.

5.0 CRITICAL HABITAT CONSIDERATIONS

The project area contains Critical Habitat for all three Snake River salmon Evolutionarily Significant Unit (ESU) stocks, Snake River Basin Steelhead, Upper and Middle Columbia River Basin Steelhead, and Upper Columbia River Spring Chinook Salmon. In designating Critical Habitat, National Marine Fisheries Service (NMFS) considers the following requirements of the species: (a) space for individual and population growth, and for normal behavior; (b) food, water, air, light, minerals, or other nutritional or physiological requirements; (c) cover or shelter; (d) sites for breeding, reproduction, or rearing of offspring; and, generally, (e) habitats that are protected from disturbance or are representative of historical geographical and ecological distributions of the species.

In addition to these factors, NMFS also focuses on the known physical and biological features (primary constituent elements) within the designated area that are essential to the conservation of the species and that may require special management considerations or protection, termed Essential Fish Habitat (EFH) pursuant to the Magnuson-Stevens Fishery Conservation and Management Act, 16 U.S.C. 1801 et seq. These essential features may include, but are not limited to, spawning sites, food resources, water quality and quantity, and riparian vegetation [50 CFR 424.12(b)], and can generally be described to include the following: juvenile rearing areas, juvenile migration corridors, areas for growth and development to adulthood, adult migration corridors, and spawning areas. Within these areas, essential features of Critical Habitat include adequate: substrate, water quality, water quantity, water temperature, water velocity, cover/shelter, food, riparian vegetation, space, and safe passage conditions. Adjacent riparian area is defined by NMFS as the area adjacent to a stream (river) that provides the following functions [components of Properly Functioning Habitat (PFH) or Properly Functioning Condition (PFC)]: shade, sediment transport, nutrient or chemical regulation, streambank stability, and input of large woody debris or organic matter.

Section 9 of the ESA makes it illegal to “take” a threatened or endangered species of fish. The definition of “take” is to “harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct” [16 U.S.C. 1532(19)]. The NMFS interprets the term “harm” in the context of habitat destruction through modification or degradation as an act that actually kills or injures fish.

Visual surveys of 1934 sounding data used to recreate the pre-dam lower Snake River channel (USACE, 1999) demonstrate that an unimpounded large class river is primarily composed of greater than 70 percent shallow water habitat. This habitat is in the form of opposing deposition bars of sand for most flow years and at least 50 to 60 percent shallow water habitat for very high flow years. It is possible that 10 percent of the lower Snake River could have constituted deep water.

The filling of Lower Granite reservoir in 1975 inundated the historical shallow water habitat. This converted approximately 40 to 60 percent of the shallow water sand bar habitat used by juvenile fall chinook salmon into either mid-depth bench habitat, more suitable for white sturgeon (with minimal structural cover) or adults of resident predator species (with structure in the substrate) or deep water habitat used by few species (table K-3). An analysis of limiting

conditions for reservoir-wide habitat readily indicates that low gradient, open sand, shallow water habitat (with no additional cover structure) suitable for fall chinook salmon rearing habitat, should be the objective target for maximizing beneficial use of in-water disposal of dredged material.

To determine the minimum surface acreage of habitats to be created, pre-impoundment aerial photos of the shorelines of the lower Snake River were studied and the sandy, shallow water areas conducive to rearing fall chinook salmon were measured. Historically, a wide size range of these habitats existed but a minimum surface area for shallow water habitat creation was designated as 4 acres (1.6 hectares). This acreage was actually lower than the average habitat area found pre-impoundment but was calculated as the minimum necessary to attempt to mimic the free-flowing shoreline required by fall chinook salmon.

Table K-3. Absolute and Relative Quantification of Three Water Depth Habitats in Lower Granite Reservoir, Snake River (SR), and Clearwater River (CR) During the Early to Mid-1980's.

Reservoir Reach (RM)	Shallow (less than 20 ft) Acres (Percent)	Mid-Depth (20 to 60 ft) Acres (Percent)	Deep (greater than 60 ft) Acres (Percent)	Total Acres (Percent of Total Reservoir or Reach)
SR107.4 – SR120.46	281 (8%)	1,241 (34%)	2,147 (57%)	3,669 (43%)
SR120.46 - SR146.33	983 (8%)	2,795 (58%)	1,017 (21%)	4,795 (57%)
SR107.4 – SR146.33	1,264 (15%)	4,036 (48%)	3,164 (37%)	8,464 (94%)
CR0.0 - CR4.4	349 (71%)	141 (29%)	0 (0%)	489 (6%)
SR107.4 - SR146.33 and CR0.0 - CR4.4	1,612 (18%)	4,177 (47%)	3,164 (35%)	8,953 (100%)
Notes: (1) Estimates calculated from U.S. Army Corps of Engineers cross section profiles. (2) SR120.46 is the mid-reservoir section where the majority of the fine silt and sand material settles out due to increased rate of depth affecting the slowing rate of water velocity.				

Apart from this comparison between the abundance and suitability of historical versus existing shallow water sandbar habitat, very few of the EFH components that existed along the shoreline of the lower Snake River reservoirs have been modified or eliminated in the recent past due to maintenance dredging. On the other hand, other associated human activities and economic growth along the shorelines have resulted in some modification of habitat that introduced additional needs for dredging. The two EFH components that may have been influenced by confluence dredging in the past are juvenile migration corridor and adult migration corridor. Specifically, the essential features of substrate, water quality, food (as in macroinvertebrate production), and safe passage conditions were affected. Adjacent to the footprint boundary for dredging in the confluence is a critically important juvenile rearing area for fall chinook salmon in the embayment of Wilma (Snake RM 134). The existing open, sandy, shallow-water rearing

habitat within Wilma remains protected from modification of any bathymetric feature and will not be affected by the proposed dredging in the main stem channel. Dredging activities will be confined to the in-water work window or in off-channel areas when water temperatures exceed 70 °F (21.1 °C) (when no or very few salmonids would be either migrating or requiring pre-migration rearing) so exposure to short-term increases in turbidity should not exist. Dredging is not allowed at elevations below the existing channel bottom contours because removal of input sand and silt is the target; hence, native substrate classes of cobble and gravel suitable for spawning should not be affected. It has been routinely shown that macroinvertebrates displaced by dredged material removal aid in colonizing or supplementing existing populations at the in-water disposal sites. Populations at the removal site also become re-colonized relatively rapid depending upon season. Both locations are also influenced through the mechanism of drift. (Bennett et al., 1990, 1991, 1993a, 1993b, 1995a, 1995b; Bennett and Nightingale, 1996)

The EFH components that may be influenced by dredging in the boat basins and/or their approaches from the main channel are juvenile rearing areas, juvenile migration corridors, and adult migration corridors. Specifically affected essential features would be substrate, water quality, water velocity, food (as in macroinvertebrate production), and safe passage conditions. Boat basins and HMU water intake basins fill with fine substrate dominated by silt that is not suitable substrate preferred by salmonids. In addition, high use by recreational boat traffic can limit the basin's suitability for salmonid rearing. Dredging activities will be confined to the in-water work window or in off-channel areas when water temperatures exceed 70 °F (21.1 °C) (when no or very few salmonids would be migrating or rearing) so exposure to short-term increases in turbidity should not exist. Removal of unsuitable size classes of substrate should not have a negative effect. These areas will be dredged by mechanical means to virtually eliminate the possibility of entrainment of any juvenile salmonid that may be present. However, if hydraulic means is chosen, it would be limited to HMU irrigation intakes and would use fish exclusion techniques. Water velocities will not be affected since these areas are functionally shallow water back eddies more suitable for resident fish. Macroinvertebrates displaced by dredged material removal can aid in colonizing or supplementing existing populations at the in-water disposal sites and populations at the removal site become recolonized relatively rapid depending upon season. Substrate quality in boat basins that have not been dredged in a number of years, such as the Hells Canyon Resort Marina, add an additional concern with the potential for the accumulation of bound contaminants in the silt as a result of both spillage from recreational watercraft fueling and activities and those brought downriver that settle in the backwater eddy environment. Recent sampling in these basins indicates that concentrations of contaminant indicators are below the level that would preclude their disposal in water. In the event that a pocket of visually contaminated sediments is hauled up in the clamshell or bucket, the Corps would direct that such an area be classified and investigated as Hazardous Waste and deposited in a truck for removal to an appropriate established waste disposal site.

Some of the EFH components may be potentially influenced by dredging in the lock approaches of lower Snake River dams. Specifically, the essential features of substrate, water velocity, cover/shelter, and possibly food (as in macroinvertebrate production) may be affected. Prior to dredging, these areas will be surveyed for redds according to established protocol (Dauble et al., 1995) to determine if modifications to velocity and substrate could cause salmon to avoid these

areas for spawning. If redds are found and verified, the location and duration of dredging will be modified to avoid the area.

The Corps believes that periodic maintenance dredging performed on a schedule of every 2 to 3 years and contained entirely within the previously disturbed footprint would not degrade the suitability of that habitat for Snake River Spring/Summer-Run and/or Fall-Run Chinook Salmon, and/or Snake or Middle Columbia River Basin Steelhead, thus not adversely modifying Critical Habitat or EFH components of that Critical Habitat. This determination is made because the area is used primarily as a migration corridor for all life stages of these stocks. Migration of each life stage of each stock has terminated for the brood years with two exceptions: (a) the potential for utilization of the submerged shallow water for rearing and feeding by chinook and steelhead and (b) some adult migration by B-run steelhead to upriver tributaries to hold for spawning in the following spring. None of the known or potential areas used by fall chinook for rearing will be disturbed by any dredged material removal action.

6.0 SUMMARY

- Inflow of sediment into Lower Granite reservoir and other lower Snake River reservoirs has created reservoir management problems including loss of depth for unrestricted navigation.
- Twelve sediment reservoir management alternatives were examined to alleviate these problems; six examined the potential for in-water disposal while six examined upland disposal. Six alternatives provide for increasing the height of the levees in the Lewiston/Clarkston areas along with either in-water or upland disposal.
- Biological criteria were established that examine aspects of the life cycle of salmonids that rear (i.e., subyearling chinook salmon) and migrate through Lower Granite reservoir, for selected resident fishes (i.e., white sturgeon, salmonid predators, and game fishes), their food items, and the ecological integrity of the Lower Granite ecosystem.
- Analysis of the effects of these management alternatives on these organisms revealed a number of alternatives could have significant adverse biological effects. Those that included an expanded dredging footprint and those alternatives that provided for temporary in-water "storage" of dredged material for later upland disposal were considered biologically unacceptable.
- Maximum biological benefits of in-water disposal in the Lower Granite ecosystem have accrued from shallow water disposal. Although shallow water was biologically (i.e., maximum light penetration) defined as water less than 20 feet (6 m) in depth, maximum biological benefits accrued from creating shoreline habitat with nearly proportional decreases in benefits with increasing depth.

- Biological benefits from shallow water disposal ranged from increasing rearing habitat for sub-yearling chinook salmon to increasing food abundance and habitat for resident fishes.
- Three alternatives were found to be biologically **Acceptable** (1a, 2a, 3a), three were considered **Satisfactory** (1b, 2b, 3b), and six were found to be **Unacceptable** (4a, 4b, 5a, 5b, 6a, and 6b).

7.0 RECOMMENDATIONS

Based on an in-depth review of a variety of biological criteria, selection of a preferred alternative should be made from alternatives 1a, 2a, and 3a with less support for alternatives 1b, 2b, and 3b. Alternatives that require loss of habitat associated with increased dredging below the current river channel or temporary in-water disposal are not recommended.

7.1 Screening of Alternatives

Four alternatives should be screened from the list above by the Corps and structured around those activities (clamshell dredging and in-water disposal) that have been performed in the recent past to maintain the authorized depths in the navigation channels of the lower Snake River and McNary reservoirs (table K-4). The areas include Lake Wallula behind McNary on the Columbia River and the reservoirs behind the four lock and dam projects on the lower Snake River (Ice Harbor, Lower Monumental, Little Goose, and Lower Granite). This navigation project provides for a 14-foot (4-m) channel with at least 14 feet (4 m) over the sills at each of the locks and 14-foot by 250-foot (4-m by 76-m) channels providing access to port and barge loading facilities in each reservoir. Sediment has been deposited over time, reducing the navigation clearances in places in each reservoir and reducing the flood flow conveyance capacity of the upper reservoir behind Lower Granite.

Table K-4. Final Alternatives Proposed in the DMMP/EIS Following Screening.

Comparison of Alternatives				
Alternative	Dredging Requirement	Dredged Material Disposal	Levee Modification	Relocation/ Acquisition Requirements
1 - "No Action (No Change)" -Maintenance Dredging With In-Water Disposal	Maintenance	In-Water - Primarily to Create Shallow Water Fish Habitat	None	None
2 - Maintenance Dredging With Strategic In-Water Disposal and a 3-Foot (0.9-m) Levee Raise	Maintenance	In-Water to Create Shallow Water Fish Habitat	Raise levees up 3 feet (0.9 m) to provide enhanced flood conveyance	Limited raising of roadways
3 - Maintenance Dredging With Upland Disposal and a 3-Foot (0.9-m) Levee Raise	Maintenance	Upland at "Joso" site in Lower Monumental Reservoir	Raise levees up 3 feet (0.9 m) to provide enhanced flood conveyance	Limited raising of roadways
4 - Maintenance Dredging With Beneficial Use of Dredged Material and a 3-Foot (0.9-m) Levee Raise	Maintenance	Beneficial Use	Raise levees up 3 feet (0.9 m) to provide enhanced flood conveyance	Limited raising of roadways; disposal sites provided by sponsor

7.2 Preferred Alternative

The Corps selected a preferred alternative from the screened alternative list and formulated a Recommended Plan for long-term management of dredging. Alternative 4 - Maintenance Dredging With Beneficial Use of Dredged Material and a 3-Foot (0.9-m) Levee Raise would best meet environmental criteria based upon restoration of juvenile salmonid habitat including opposing sandbars used by Snake River fall chinook salmon that out-migrate as subyearlings. Alternative 4 incorporates mitigation features that act to restore valuable shallow water sand bar habitat to the Lower Granite ecosystem. Other proposed non-in-water beneficial uses of dredged material may be adopted on a case-by-case basis under this plan as opportunities become available and when local sponsors agree to fulfill sponsorship requirements. To ensure that the plan continues to optimize the use of dredged material, the Local Sediment Management Group (LSMG) has review responsibilities for the disposal practices for each dredging season and may suggest modification of the plan, if appropriate, as new information and opportunities for beneficial use become available.

The 3-foot (0.9-m) levee raise feature is the preferred plan for maintaining the flow conveyance capacity in the Snake and Clearwater Rivers confluence area of Lower Granite reservoir. Raising the levee was found to reduce the need for dredging in the confluence area of Lower Granite reservoir and, therefore, is considered as a part of this DMMP/EIS.

7.3 Dredging Areas and Quantities

Dredging templates were designed for the federal navigation channel in each reservoir to achieve the maintenance dredging requirements. For the Lower Granite reservoir, the areas that require dredging for navigation are located on the Clearwater River between the Snake River confluence and the Port of Lewiston, located between Clearwater RM's 0.00 and 1.56 and on the Snake River from the vicinity of Silcott Island near Snake RM 131 upstream to the U.S. 12 bridge located near Snake RM 139.5. A range of dredged volumes between 16,000 and 300,000 CY (12,233 and 229,367 m³) would be required on a 2-year cycle to develop and maintain the designed navigation channels in the Lower Granite reservoir. An estimated 4,000 CY (3,058 m³) would be dredged from behind Little Goose, and 2,000 CY (1,529 m³) from behind Lower Monumental and Ice Harbor at 2-year intervals. The areas to be dredged in each case are located at the upstream end of each reservoir. The maintenance dredging for the McNary reservoir is estimated to be approximately 32,000 CY (24,466 m³) every 2 years.

Dredging should be accomplished use a clamshell dredge of approximately 15-CY (12-m³) capacity discharging to a barge with a capacity of 3,000 CY (2,294 m³). The barges should have a maximum size of 240 feet (73 m) long by 42 feet (13 m) wide with a maximum draft of 14 feet (4 m). The expected rate of dredging is 5,000 CY (3,823 m³) per 8-hour shift. Dredging should be performed in the Snake River during the period of December 15 through March 1 and for a longer period from December 1 to March 30 in the Columbia River. Multiple shift dredging workdays should be used when necessary to ensure that dredging is completed within these windows. In addition, some amount of dredging in backwater areas may occur when near-shore water temperatures exceed 68 °F (20 °C), a thermal barrier for salmonids.

All material dredged in the Lower Granite reservoir should be disposed of downstream of Centennial Island located near Snake RM 120.5. Proposed disposal areas are along opposing submerged sand and silt composed bars several hundred feet in length, primarily in Lower Granite reservoir. Seven sites have been identified for restoration of shallow water rearing habitat (see table K-5).

Table K-5. Proposed In-Water Disposal Sites Within Lower Granite Reservoir for Restoration of Shallow Water Rearing Habitat for Juvenile Snake River Fall Chinook Salmon.

Site Number	Location (RM)	Description (Landmark)	Final Disposal Depth Range	Acres	Site Capacity (MCY)
1	119.5-120.5	Kelly Bar/ Centennial Island - Left Bank	Shallow and Mid - Completed in 1998	48.6	
2	117.5-119.0	Blyton Landing/ Yakawawa Canyon - Right Bank	Shallow	114.6	2.5
3	115.7-117.0	Knoxway Canyon - Left Bank	Shallow	110.8	10.5
4	114.0-115.0	Upriver Granite Point - Right Bank	Shallow	144.2	3.8
5	112.5-113.5	Downriver Granite Point - Left Bank	Shallow	30.7	0.6
6	110.0-112.0	Wawawai - Right Bank	Shallow	354.8	12.0
7	108.0-109.8	Offfield Landing - Left Bank	Shallow	218.4	5.3
Total				1,022.1	35.0

Beginning in year 1, in-water disposal should occur on the underwater bench at RM 116, immediately upriver of Knoxway Canyon in Lower Granite reservoir. The Knoxway Canyon site has a capacity of 10.5 million CY (8,027,830 m³) to achieve the design components for shallow water habitat. Assuming 300,000 to 400,000 CY (229,367 to 305,822 m³) of dredging removal per year or every 2 years, it could take 20 years just to achieve the capacity allowed by the Knoxway Canyon site.

An alternate disposal option could include sand deposition initiated at the downriver end of Lower Granite reservoir at the Offfield Landing site and proceed upriver from Lower Granite towards the Knoxway Canyon site. Materials would be deposited in shallow and mid-range water disposal areas to restore shallow water habitat wherever possible. The entire channel below elevation 670 feet msl is available to be used for material disposal as required. Sands, gravels, and cobbles, expected to comprise 85 percent of the total material, would be dumped in the shallow to mid-range depths from 15 to 35 feet (5 to 11 m) to form shallow water habitat. Approximately 15,000 CY (11,468 m³) of dredge material would be deposited per acre. A beam drag would be used to flatten and level the tops of the piles to form a flat shallow area of between 10 and 15 feet (3 and 5 m) in depth that is suitable for fish habitat. The remaining 15 percent of material that is silt or finer would be mixed in the load with sand to be deposited as base material for shallow water habitat to be built upon. Deep-water disposal provides no beneficial use to aquatic organism productivity; thus, deep-water disposal is not proposed or planned to occur.

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